

UNIVERSITY OF CALIFORNIA PUBLICATIONS

COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

INVESTIGATIONS WITH MILKING MACHINES

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BULLETIN No. 311

SEPTEMBER, 1919

UNIVERSITY OF CALIFORNIA PRESS
BERKELEY
1919

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INVESTIGATIONS WITH MILKING MACHINES

F. W. WOLL

Milking machines have now been successfully operated in dairy herds in different parts of the country for more than a quarter of a century, and in many dairies several generations of cows have been milked by machines during this period. Owing to the difficulty of securing efficient and reliable milkers in recent years, especially while war conditions prevailed, machine milking has been adopted in a rapidly increasing number of American dairies during this period, and there are now perhaps few dairy sections in the country where milking machines have not been installed and are operated successfully.

Practical experience with milking machines and numerous investigations of the work of different makes of machines conducted by experiment stations during the last decade or two have fully established the practicability and the economy of modern milking machines by this time; as a result, there is at present a constant and, in many sections, a rather rapid transition from hand to machine milking in American dairy herds. This transition is retarded in some cases by a doubt in the minds of dairy farmers, perhaps especially by owners of valuable pure-bred herds, as to whether the cows will do quite as well when milked by machine as by hand, and whether machine milking will not necessarily have a tendency, at least in the case of some cows, to reduce their milk production for entire lactation periods as compared with hand milking, even if this would not be sufficiently marked to interfere appreciably with their future usefulness as dairy producers. Failures of certain milking machines in the case of individual herds, and the fact that conditions and results obtained in other sections are not known, doubtless account for this questioning by some dairy farmers of the practical value of milking machines.

The investigations of milking machines in the University dairy herd reported in this bulletin were commenced in the spring of 1915 with a special view to ascertaining the effect of long periods of machine milking on the dairy production of cows. The plan of the investigations especially aimed at furnishing definite evidence on the question of whether or not machine milking involves any risk in regard to the continued efficiency of dairy cows, and the results should be of special

interest and value to dairymen who may be more or less in doubt with regard to this point. It is believed that the results herewith presented will also be of value to other dairy farmers who have not as yet seriously considered the matter of installing milking machines in their herds, and will clear up various points in connection with the operation of the machines, concerning which there may be a question.

At the time this investigation was commenced there were at least three different makes of milking machines on the market in this country that had been found to do satisfactory work when operated in accordance with the direction of manufacturers, and that had been more or less thoroughly investigated by American experiment stations. Considerable literature on the subject of milking machines had been published by these stations which, generally speaking, furnished conclusive evidence as to the value of this method of milking. During the last three years the number of different milking machines placed on the market, and the published reports of investigations of these have been further increased (see partial bibliography, pp. 54); frequent discussions on the subject of machine milking in our agricultural and dairy press have likewise greatly enlarged our knowledge of different types of milking machines and of their practicability under present conditions of dairying.

Two different makes of machines were employed in this investigation, viz., the "Calf-Way" Milker, during the first three years, and the Empire Milking Machine for the past year, operated either alone or along with the "Calf-Way" Milker. The latter machine is an improved type of the Hazelwood milking machine, which was manufactured by a Spokane, Washington, firm and introduced in a number of western dairy herds about a dozen years ago.* The direct occasion for taking up this study was the fact that no report on the character of the work done with the "Calf-Way" Milker had been published at the time. Gradually, however, the investigation was broadened so as to cover the scope stated above. At first one string of cows in the University dairy herd was milked by machine and the balance by hand, but during the last year and a half nearly all milch cows in the herd were milked by machine throughout the lactation period.

*The state agents, with addresses, of these two and other milking machines at present on the market in this state are as follows:

Burrell (B-L-K); Baker, Hamilton & Pacific Co., San Francisco.

"Calf-Way"; Calf-Way Milker Co., San Francisco.

De Laval; De Laval Dairy Supply Co., San Francisco.

Empire; J. N. Blair & Co., Sacramento.

Hinman, C. F. Daniells, Hughson, Cal.

Perfection, H. F. Lingg Co., 1901 Grant Street, Berkeley.

Sharples; The Sharples Separator Co., San Francisco.

Universal; California Hydraulic Engineering Co., San Francisco.

The general plan of the experiments was to continue the cows on the milking machine for one or more complete lactation periods so as to secure accurate data as regards the total milk production and the rate of decrease, if any, in the milk flow during the lactation that may result from machine milking. Data concerning the immediate effect of changes in the method of milking practiced, from hand to machine and *vice versa*, were also obtained. The milk from each milking for the individual cows was weighed and sampled separately, composite samples for each cow being tested regularly once a week for content of solids and butter fat; bacteriological examinations of the milk from individual cows were also made from time to time to determine to what extent milk drawn by machine comes up to modern sanitary standards.

During the progress of this investigation a total of 78 cows were machine-milked for periods ranging from a few weeks to three complete lactation periods. The cows included 34 grades (mostly grade Holsteins), and the following number of pure-breds: 20 Holsteins, 12 Jerseys, 10 Guernseys and 2 Ayrshires. The method of milking adopted for a given period in case of individual cows was at times necessarily determined by other considerations than those coming within the plan of this investigation; with pure-bred cows especially by the chances of their making creditable yearly records; but in the main the original plan was adhered to insofar as cows were generally milked by machine for one or more complete lactation periods.

In comparing the results obtained by machine milking with those obtained by hand milking for the cows included in the investigation, data showing the immediate effect of a change from hand to machine milking, and *vice versa*, will be presented, followed by data for entire lactation periods.

IMMEDIATE EFFECT OF A CHANGE IN THE METHOD OF MILKING

The immediate effect of the method of milking practiced may be traced from the results for the production of milk and butterfat for two weeks prior to and following the period of machine and hand milking, respectively, as shown in Table I. Periods close to the beginning or to the end of a lactation period, when the milk production was either not yet up to normal or was abnormally low because of the cow being dried up, were excluded from the compilations.

TABLE I.—IMMEDIATE EFFECT OF A CHANGE FROM HAND TO MACHINE-MILKING

Cow	I. Hand—2 weeks before M. M.			II. Machine—first 2 weeks			III. Machine—second 2 weeks		
	Milk	Fat	% Fat	Milk	Fat	% Fat	Milk	Fat	% Fat
Korndyke.....	638.6	20.75	3.25	571.3	19.42	3.40	534.0	16.29	3.05
Nora.....	336.3	16.82	5.00	311.0	18.03	5.80	300.3	15.02	5.00
Atlantis.....	464.7	20.45	4.40	461.5	20.30	4.40	408.4	17.55	4.30
University.....	504.6	19.42	3.85	457.7	16.47	3.60	395.8	12.66	3.20
Santa.....	146.4	9.22	6.30	144.5	8.67	6.00	121.9	7.31	6.00
Langwater.....	196.0	8.53	4.35	182.6	8.04	4.40	174.5	7.33	4.20
Pearl.....	227.4	10.91	4.80	229.9	10.95	4.76	227.7	10.48	4.60
Fern Ridge.....	148.6	8.39	5.71	106.9	5.95	5.57	67.6	3.48*	5.15
Fern Ridge.....	317.0	15.97	5.04	243.6	11.08	4.88	207.3	9.32	4.50
Roania.....	350.7	13.18	3.76	350.1	13.13	3.75	349.4	11.71	3.35
Roanie.....	275.1	9.80	3.56	206.2	7.53	3.68	188.7	7.03	3.73
Queen.....	421.8	14.57	3.45	397.0	12.54	3.16	317.2	9.32	2.94
Queen.....	683.2	24.28	3.55	604.8	18.73	3.10	593.2	17.80	3.00
Agnes.....	701.2	21.08	3.01	699.7	21.72	3.10	667.8	18.70	2.80
Hannah.....	857.6	25.73	2.97	885.3	24.79	2.80	738.2	21.06	2.85
University II.....	569.9	20.80	3.65	572.6	17.80	3.11	551.2	19.17	3.78
Beauty.....	272.8	14.23	5.22	261.3	13.46	5.15	246.7	12.09	4.90
Lorena.....	559.6	22.06	3.94	476.7	15.47	3.25	476.0	15.45	3.25
Bess.....	748.9	25.84	3.45	642.8	18.10	2.82	633.9	18.38	2.90
Jean.....	269.0	8.90	3.31	252.3	8.63	3.42	267.3	8.49	3.18
Juanita.....	383.9	13.05	3.40	376.6	13.76	3.65	352.7	13.15	3.73
Nora II.....	324.5	14.07	4.32	290.5	14.83	5.10	272.9	13.30	4.88
Roxey.....	472.2	19.87	4.21	387.8	17.81	4.58	395.1	17.66	4.47
Julie.....	202.7	8.86	4.37	242.4	9.57	3.95	229.9	8.61	3.75
Begonia.....	377.9	16.83	4.45	361.2	16.98	4.70	334.2	16.99	5.08
Inka.....	468.3	17.33	3.70	438.2	17.75	4.05	436.0	17.23	3.95
Bunny.....	185.5	10.10	5.44	171.0	9.31	5.45	158.2	8.70†	5.50
Cherry.....	452.2	17.18	3.80	412.0	17.31	4.20	385.2	15.21	4.21
Agnes II.....	558.8	20.60	3.69	545.8	18.54	3.40	514.5	16.78	3.26
Questa R.....	217.2	10.09	4.65	206.7	9.29	4.49	198.8	8.73	4.39
Jap.....	275.2	14.24	5.17	267.7	15.92	5.95	262.3	15.72	5.76
Averages(31 periods, 28 cows)	406.7	15.91	3.91	379.3	14.58	3.84	359.1	13.25	3.73
Percentage decrease.....	.....	.....	.....	6.7	8.4	.07	6.4	9.1	.11

*Dry 10 days afterwards.

†Three weeks from calving.

TABLE II.—IMMEDIATE EFFECT OF CHANGE FROM MACHINE TO HAND-MILKING

Cows	Machine—2 weeks before H. M.			Hand—first 2 weeks			Hand—second 2 weeks		
	Milk	Fat	% Fat	Milk	Fat	% Fat	Milk	Fat	% Fat
Nora.....	87.9	6.16	7.01	73.7	5.43	7.37	57.0	3.98	6.98
Nora.....	351.1	18.06	5.14	342.6	18.80	5.49	307.4	16.17	5.26
Atlantis.....	108.8	4.98	4.58	108.2	4.92	4.55	105.9	4.95	4.67
Atlantis.....	311.2	13.53	4.35	289.2	14.01	4.84	252.5	12.61	4.99
University.....	131.8	4.09	3.10	146.1	5.76	3.94	192.2	6.53	3.40
Langwater.....	139.8	6.21	4.44	157.6	6.84	4.34	173.8	6.71	3.87
Pearl.....	111.8	5.77	5.16	99.3	5.21	5.25	73.0	3.86	5.29
Roanie.....	381.0	12.41	3.26	389.5	13.05	3.35	338.9	13.03	3.84
Willowmoore.....	191.3	9.12	4.77	108.5	5.30	4.83	67.9	3.40	5.01
Payne.....	274.0	8.35	3.05	221.0	6.43	2.91	173.1	5.45	3.15
Beauty.....	192.3	10.11	5.25	150.4	9.48	6.30	136.3	7.17	5.26
Lorena.....	476.0	15.45	3.25	442.6	14.38	3.25	424.5	15.50	3.65
Helen.....	86.5	3.41	3.94	81.2	2.86	3.52	89.4	3.53	3.95
Fern.....	64.3	3.51	5.46	57.7	3.16	5.48	42.9	2.40	5.59
Jean.....	330.2	12.12	3.70	310.3	9.46	3.05	292.9	9.28	3.17
Barbara.....	140.7	6.26	4.45	108.0	5.06	4.69	77.7	3.64	4.68
Inez.....	154.6	6.09	3.94	114.9	4.92	4.28	81.2	3.36	4.14
Roxey.....	140.7	7.06	5.02	106.9	5.15	4.82	109.9	5.27	4.80
Averages (18 periods, 16 cows)	204.1	8.48	4.15	183.8	7.79	4.24	166.5	7.05	4.23
Decrease, in per cent.....	.....	.....	.....	9.9	8.1	+ .09	9.4	9.5	.01

It will be noted that data for 28 cows (31 periods in all) are given in Table I for two weeks before the change from hand to machine milking, and for the first and the second two-week periods on machine milking. The average production of milk during these periods was 406.7 lbs., 379.3 lbs. and 355.1 lbs., respectively; a difference of 27.4 lbs. between the average yield during the last two weeks on hand milking and the first two weeks on machine milking, and of 24.2 lbs. between the average yield during the first two periods on machine milking, i.e., a decrease in milk production during the latter periods of 6.7 and 6.4 per cent., respectively. In the same way, the average production of butter-fat decreased 1.33 lbs. both going from hand milking to machine milking and during the first two periods on machine milking:—a percentage decrease of 8.4 and 9.1 for the two periods. The per cent. of fat in the milk dropped, on the average, .07% on the second period and .11% on the third period. All but four cows went down in milk going from hand to machine milking, and all but two went down going from the first to the second machine-milking periods, the corresponding figures for production of butter-fat being ten and four. As regards the average percentage of butterfat, it will be seen that there was an increase during period II over period I in the case of 14 cows, and a decrease in the case of 16 cows; no change occurring in the quality of milk from one and two cows for periods II and III, respectively.

Considering now the data presented in Table II, showing the immediate effect of changing from machine to hand milking, we note that the average production of milk for 16 cows (eighteen trials) on machine milking was 204.1 lbs.; on first hand-milking period, 183.8 lbs.; and on second hand-milking period, 166.5 lbs.; a decrease of 9.9% and 9.4%, respectively, in production of milk, during periods II and III the decrease in production of butter fat for these periods being 8.1 and 9.5 per cent., respectively.

There was, therefore, a somewhat smaller decrease in the average milk production during the first period of hand milking following machine milking than during the second hand-milking period, but the decrease in average yield of butter fat was slightly higher during the latter period, both absolutely and relatively, than going from machine milking to hand milking.

Comparing the results given in this table with those obtained by changing in the opposite direction, from hand to machine milking, as shown in Table I, it will be noted that the figures for the decrease in production during the two periods following the change in the method of milking differ only slightly. There was a somewhat greater decrease in the production of both milk and butter fat on changing from machine

to hand milking than when a change in the opposite direction was made. This may be explained from the fact that the cows included in the latter compilation were, in general, farther advanced in their lactation than those furnishing the data included in Table I (221 vs. 115 days from freshening, on the average, at the beginning of the first period), since the normal decrease in production, as a general rule, is greater toward the close of the lactation period than early in the lactation.

The differences in the amounts of milk or butter fat obtained during brief periods immediately following a change from hand to machine milking, or vice versa, are on the whole not sufficiently marked to furnish an argument either for or against machine milking. In the case of some cows, a somewhat increased production will be obtained by machine milking, as an immediate effect of the change in the method of milking. With other cows, the opposite will hold true, and this is perhaps more likely to be the case.

As in the case of the change from hand to machine milking, there was a more or less marked decrease in production during the first two weeks after the change in the opposite direction was made; in sixteen and fourteen cases out of eighteen there was a decrease in milk and butter fat production, respectively, during period II as compared with period I, indicating that the immediate result of any change in the method of milking practised is likely to react unfavorably in the case of a large majority of cows,—a matter well understood by observing dairymen, both as relating to a change in the method of milking and to a change in milkers.

However, the immediate effect of the method of milking practised is of much less importance than the effect on the continued production of the cows during an entire lactation, or during several lactation periods. The influence of the method of milking practised on the production of the cows during long-continued periods will now be considered. This may be traced in two ways, viz.,—from the gradual decrease in production during successive brief periods of the lactation, or from the total production during the entire lactation. The results obtained in this investigation along both these lines have been compiled and are presented and discussed in the following pages.

DECREASE IN PRODUCTION DURING LACTATION PERIOD

Studies of the production of milk and butter-fat by dairy cows with the lactation period have shown that, after the maximum production has been reached shortly after freshening, there is, as a general rule, a gradual decrease in production as the lactation period advances. The exact stage of maximum production will vary with different cows,

and even with the same cows, with their body condition at the time of freshening, and with the system of feeding adopted. It will, in most cases, come within a couple of weeks from freshening, but sometimes occurs several weeks later. From this time on, there is, as a rule, a rather regular decrease in production for a period of six to eight months, and the decrease then becomes more marked until the cows are dried up, during the tenth to eleventh month of the lactation. The percentage of monthly decrease during the main part of the lactation period in the case of good dairy cows has been found to amount to about 5% of the yield of the preceding month and, during the last part becomes ten to twenty per cent. of the production during the preceding month.*

The methods of feeding, milking, and handling of the cows will determine to an appreciable extent the persistency of the milk flow and the length of the lactation period, the smallest percentage decrease being obtained in herds composed of good dairy cows that are fed liberal rations, carefully milked, and are, in general, subject to conditions most favorable to a continued large dairy production.

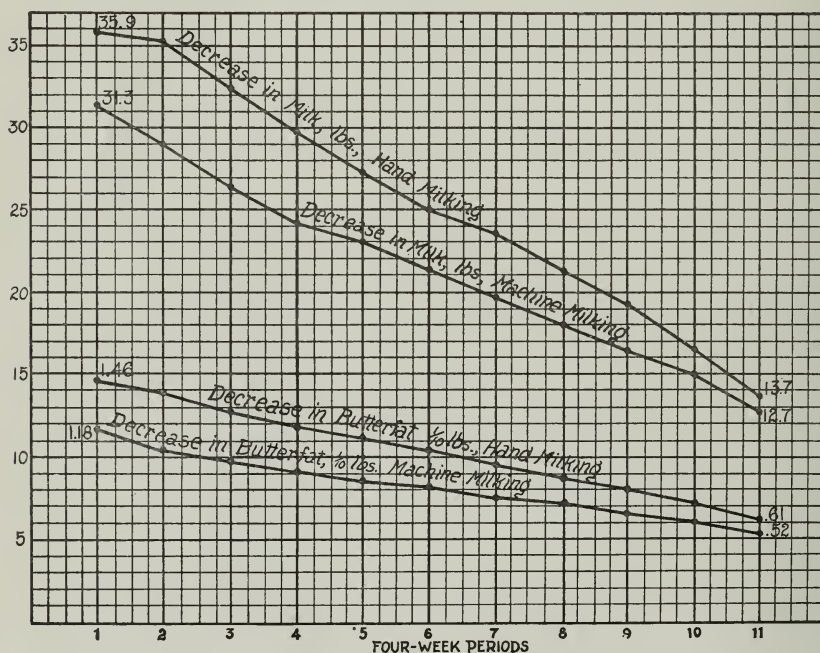


Fig. 1

*Wis. Station Bulletin 102 and Research Bulletin 26; Geneva (New York) Station Report 1886, p. 21; Kentucky Station Bulletin 106; California Station Bulletin 301.

Complete data bearing on this point are available for about fifty cows in the university dairy herd, for machine and hand milking, respectively. The following summary tables show the average daily yields of milk and butter-fat for successive periods of four weeks each, for all cows that gave milk during ten and eleven 4-week periods. Data for the latter cows are included in the second part of the table. The percentage decrease in production by the two groups for successive months are also given.

TABLE III.—PERCENTAGE DECREASE IN PRODUCTION DURING LACTATION
PERIOD FOR 4-WEEK PERIODS

	Ave. daily milk yield, lbs.		Decrease in per cent.		Ave. daily butterfat yield, lbs.		Decrease in per cent.	
	Mach.	Hand	Mach.	Hand	Mach.	Hand	Mach.	Hand
No. of cows included	54	52	....	....	54	52	....	....
1st 4-week period	31.9	34.7	....	....	1.17	1.42	....	....
2nd 4-week period	29.2	33.7	8	3	1.05	1.34	10	6
3rd 4-week period	26.5	31.3	9	7	.97	1.25	8	7
4th 4-week period	23.9	28.7	10	8	.90	1.16	7	7
5th 4-week period	22.5	26.6	6	7	.84	1.08	7	7
6th 4-week period	20.8	24.7	8	7	.79	1.01	6	6
7th 4-week period	19.4	22.8	7	8	.74	.93	6	8
8th 4-week period	17.8	20.4	8	11	.70	.85	5	9
9th 4-week period	16.1	18.2	10	11	.64	.76	9	11
10th 4-week period	14.1	15.3	11	16	.57	.66	11	14
Difference, 1-5th mo.	.....	.....	29.5	23.3	.....	.....	28.2	23.9
1-10th mo	.....	.....	54.9	55.9	.....	.....	48.7	53.5
No. of cows included	43	41	....	....	43	41	....	....
1st 4-week period	31.3	35.9	....	....	1.18	1.46	....	....
2nd 4-week period	29.0	35.2	7	2	1.05	1.39	11	5
3rd 4-week period	26.4	32.4	9	8	.98	1.28	7	8
4th 4-week period	24.1	29.8	9	8	.91	1.19	7	7
5th 4-week period	23.0	27.4	5	8	.86	1.11	5	7
6th 4-week period	21.3	25.0	7	9	.81	1.04	6	6
7th 4-week period	19.8	23.6	7	6	.76	.95	6	9
8th 4-week period	18.0	21.2	9	10	.71	.88	7	7
9th 4-week period	16.4	19.2	9	9	.66	.80	7	9
10th 4-week period	15.0	16.5	9	14	.60	.71	9	11
11th 4-week period	12.7	13.7	15	17	.52	.61	13	15
Difference, 1-5th mo.	.....	.....	26.5	23.7	.....	.....	27.1	24.0
1-11th mo.	.....	.....	59.4	61.8	.....	.....	55.9	58.2

The data for the percentage decrease in production presented in Table III suggest that the production of both milk and butter fat by the machine-milked cows decreased, on the average, somewhat more rapidly than that of the hand-milked cows during the early months of the lactation period, and that it was somewhat lower during the latter part of the same. Between the first and the fifth monthly period the

milk production went down 29.5% for the machine-milked cows that gave milk during ten complete 4-week periods, against 23.3% for the corresponding hand-milked group; the decrease in production of butter fat for this period was 28.2% for the machine-milked cows against 23.9% for the hand-milked cows. On the other hand, if the yields during the first and the tenth monthly periods be compared, it will be seen that the machine-milked cows decreased on the average 54.9% in milk and 48.7% in butter fat, against 55.9% and 53.5%, respectively, for the hand-milked cows. Results agreeing closely with these were obtained for the cows in milk for eleven complete 4-week periods.

It will be noted that the average daily yields of milk and butter-fat for hand milking given in the table are always somewhat higher than those for machine milking, the reason being that, when milked by hand, the cows were in many cases fed more liberal rations, and therefore produced more heavily than when machine milked, as will be seen presently. Data for the same cows were included in both groups in many cases, but the two groups were not composed of the same cows; all available records obtained on machine milking were included in the compilations given in Tables III and IV and a similar number of records for hand-milked cows in the herd were selected at random for comparison from the herd records.

The average quality of the milk produced by the two groups of cows will be seen from Table IV.

TABLE IV.—AVERAGE PER CENT. OF FAT IN MILK DURING SUCCESSIVE PERIODS

	Machine	Hand	Machine	Hand
No. of cows included.....	54	52	43	41
1st 4-week period.....	3.67	4.09	3.77	4.07
2nd 4-week period.....	3.60	3.98	3.62	3.98
3rd 4-week period.....	3.66	3.99	3.71	3.95
4th 4-week period.....	3.77	4.04	3.78	3.99
5th 4-week period.....	3.73	4.06	3.74	4.05
6th 4-week period.....	3.80	4.09	3.80	4.06
7th 4-week period.....	3.81	4.08	3.84	4.03
8th 4-week period.....	3.93	4.17	3.94	4.15
9th 4-week period.....	3.98	4.18	4.03	4.17
10th 4-week period.....	3.96	4.31	4.00	4.31
11th 4-week period.....	.....	.....	4.09	4.38
1-5 increase in % of fat.....	+ .06	— .03	.....	.....
1-10 increase in % of fat.....	+ .29	+ .22	.....	.....
1-5 increase in % of fat.....	.....	.....	— .03	— .02
1-11 increase in % of fat.....	.....	.....	+ .32	+ .31

It will be noted from Table IV that the changes in the average quality of milk during the progress of lactation periods are fully normal and quite similar in the case of both machine and hand-milked cows; they are apparently independent of the special method of milking practised (see figs. 1 and 2).

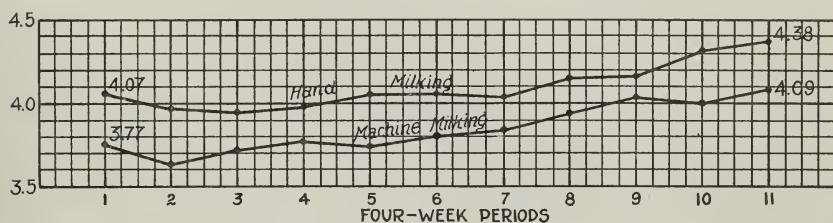


Fig. 2

It is of interest to compare the results given in Table III for the rate of decrease in production with the progress of the lactation period with similar data obtained in dairy herds in this and other states. We select as typical the average data secured for cows entered in the California State Dairy Cow Competition and similar findings for cows in the dairy herd of the Wisconsin Experiment Station, and in pure-bred herds owned by Wisconsin farmers.* Table V shows the results secured in these investigations. The figures for the average decrease in production of milk and butter fat during successive 4-week periods of the lactation for the herds included in these investigations have been calculated and are given in the last two columns of the table.

TABLE V.—AVERAGE DECREASE IN PRODUCTION DURING PROGRESS OF LACTATION PERIOD

	Cal. Dairy Cow Comp'tion		Wisconsin Station Herds		Wisconsin Dairy Herds		Averages	
	Milk	Butter-fat	Milk	Butter-fat	Milk	Butter-fat	Milk	Butter-fat
Ave. yield 1st mo., lbs.....	46.4	1.95	31.0	1.34	43.9	1.76	.....	.....
Decrease in per cent.:								
2nd 4 weeks.....	+1	+1	6	10	5	6	3	5
3rd 4 weeks.....	9	9	7	8	7	7	8	8
4th 4 weeks.....	7	5	8	7	6	5	7	6
5th 4 weeks.....	7	6	5	5	5	5	6	5
6th 4 weeks.....	7	6	4	2	5	5	5	4
7th 4 weeks.....	9	7	7	8	6	5	7	7
8th 4 weeks.....	11	9	10	6	10	9	10	8
9th 4 weeks.....	9	8	11	6	13	11	11	8
10th 4 weeks.....	11	11	.....	.....	20	15	16	13
Total decrease, 1-5th mo.....	20.7	16.9	24.2	26.9	21.2	21.0	22.0	21.6
1-10th mo.....	51.1	45.1	54.5	50.8	56.3	50.6	54.0	48.8

*Cal. Station Bulletin 301; Wisconsin Station Bulletin 102 and Research Bulletin 26.

The figures given in Table V were in practically all cases obtained by hand milking and are therefore directly comparable to the results previously given that were obtained by this method of milking with cows in the university dairy herd. In the majority of cases they were obtained with pure-bred cows and represent the best modern dairy practice as adopted by leading dairymen. Comparing the average data given in the last two columns of the table with the results presented in Table III, it will be seen that the latter figures for the decrease in production with advancing lactation, as well as between the first and the last period of the lactation periods, were in most cases slightly higher than the former, in the case of both methods of milking. This is only what might be expected from the conditions under which the milking was done, in the case of the investigations quoted in Table V, and in our own milking-machine trials. As above suggested, careful milking was doubtless, as a rule, practised in most of the former herds, the cows being milked by the owners themselves or by interested help who fully appreciated the importance of their work for the development of excellent dairy qualities in cattle, and for the maintenance of a large dairy production.

On the other hand, the milking in the university dairy herd was, as a rule, done by help similar to that available in other dairy districts in the state,—a class of men who are frequently none too interested in their work and who in the large majority of cases do not remain a long time in the same place. This class of laborers are not, as a rule, likely to make good milking-machine operators, but especially during the war conditions of the past year one was glad to be able to secure any kind of help. Reference to the problem of the milker is made here in order to show that the conditions under which the investigations reported in

this bulletin were conducted were, in general, similar to those that prevail in most of the dairies in the state. The results secured are, therefore, as a rule, no better than those that may be obtained by California dairy farmers in general; in fact, it may be safely stated that they are not as good as those which a dairyman of fair intelligence and resourcefulness, who milks his own cows or who has competent reliable help may count on by machine milking.

We have seen that both in the case of the cows in the university herd giving milk during ten complete 4-week periods and those in milk for eleven such periods, the percentage decrease in milk production as well as in average yield of butter-fat during the entire lactation period was slightly higher for the hand-milked cows than for those milked by machine, an average difference of two to five per cent. occurring in the production of butter fat and of one to two per cent. in the production of

milk, both in favor of machine milking. These figures refer to the decrease in production from the first to the tenth or eleventh month of the lactation period, respectively. In view of this result, it becomes of special interest to investigate how the total production of the cows for the entire lactation period compares when the cows were machine-milked and when they were milked by hand. The available data on this point are presented and discussed below.

COMPARISON OF YIELDS FOR ENTIRE LACTATION PERIODS

In order to ascertain the effect of the special method of milking practised on the total production of the cows, the data for all complete lactation periods when the cows were machine milked have been compiled, and the average production for a corresponding number of lactation periods for hand-milked cows has been computed from the records of the university dairy herd, either for the same cows when data for complete normal lactations were available, or for other cows taken at random from the herd record book. The cows included in these compilations were milked by one or the other method during entire lactation periods, with only a few exceptions, as noted in a subsequent table. Table VI shows the average data obtained in these compilations for machine-milked and for hand-milked cows.

TABLE VI.—COMPARISONS OF YIELDS FOR ENTIRE LACTATION PERIODS

	Machine-Milking	Hand-Milking
No. of lactation periods.....	56	56
No. of different cows.....	45	40
Ave. age, years-months.....	3-7	5-0
Ave. length of lactation, days.....	351	355
Ave. production of milk, lbs.....	7385.5	7800.3
Ave. per cent. fat.....	3.84	4.14
Ave. production of butterfat, lbs.....	283.56	322.91
Corrected for difference in age.....	326.09	322.91
Highest production of milk, lbs.....	12722.5	13443.0
Lowest production of milk, lbs.....	3961.9	2670.1
Highest production of butterfat, lbs.....	588.16	558.75
Lowest production of butterfat, lbs.....	156.22	121.44
Longest lactation period, days.....	507	462
Shortest lactation period, days.....	284	254

It will be seen from the figures in Table VI that during fifty-six lactation periods (for forty-five different cows), when machine-milking was practised, the cows produced an average of 7,385.5 lbs. milk and

283.56 lbs. butter fat (average fat content, 3.84%). Similar data for fifty-six lactation periods (forty different cows) in the same herd on hand milking gave an average production of 7,800.3 lbs. milk and 322.91 lbs. butter fat, (average fat content 4.14%). Since the two groups of cows were not made up exactly of the same animals it cannot be safely assumed that the differences in average production noted were due to the difference in the method of milking practiced. There are a number of other factors that would tend to influence the production of the cows, the most important doubtless being the age of the animals making up the two groups. The machine-milked group included about 30 young heifers, mostly grades, which have been milked by machine ever since they were added to the herd in 1916 and 1917, while less than a dozen heifers were included in the hand-milked group. This factor would, of course, tend to favor the production of the group of hand-milked cows. The average age of the cows in the machine-milked group was slightly over $3\frac{1}{2}$ years, against five years for the hand-milked cows. It is known from the results of advanced-registry tests of cows of different ages belonging to the various dairy breed associations that cows will increase, on the average, about 15% in production from $3\frac{1}{2}$ to 5 years old.* It may be assumed, therefore, that if the machine-milked cows had been of the same average age as those included in the hand-milked group, they would have had an average production of 326.09 lbs. butter fat to their credit, or within one per cent the same production as the average for the hand-milked lot, indicating that the dairy production of the cows was not appreciably influenced by the special method of milking practised.

If the production of the individual cows that were below full-age be corrected on basis of an average increase of from 30 to 5%, for cows two to four and a half years old, respectively, (*loc. cit.*), and the calculated yields of butter fat per lactation for mature cows thus obtained, it will be seen that the average production for the machine-milked cows was 337.94 pounds and for the hand-milked ones 352.89 pounds. The standard deviation in the production of the former cows was 90.1, and of the latter 114.2, making the probable error of the mean of the annual yields of butter fat for machine-milked cows 8.12, and for the hand-milked cows 10.3. The difference between the probable error of the two means (obtained by extracting the square root of the sum of the two probable errors raised to the second power) is 13.1, which is but slightly less than the difference between the mean production of the two groups of cows. The difference between the mean production divided by the probable error is $14.95-13.1$, or 1.14. The probability

*California Station Bulletin 301, p. 163.

of the occurrence of a deviation of this magnitude is 44.2. There is, therefore a very slight deviation from an even chance that the difference in the yields on the two methods of milking is not caused by the special method of milking practised, but is practically within the limits of the natural variations in the production of cows kept under conditions similar to those present in the University Dairy herd.

It may be noted incidentally that the probable error of the mean in the case of the hand-milked cows was greater than that of machine-milked cows, viz., 10.3 against 8.12. The explanation of this is doubtless to be sought in the more intensive feeding practiced in the case of several of the hand-milked cows during the lactation periods when they were on Advanced-Registry tests (p. 45).

Further evidence as to the effect of machine-milking on the milk secretion may be obtained from a study of the production of the cows in the dairy herd that were milked by both methods during different lactation periods. Such data are available for thirteen cows in all, covering eighteen complete lactation periods for machine milking and twenty-one lactation periods when the cows were milked by hand.

The main data relating to the production of these cows are included in Table VII, the last two lines of which show the average production per cow and per lactation periods for both methods of milking. Owing to a variety of causes beyond our control, the number of lactation periods for the two methods differ in the case of the individual cows, and the milking-machine periods sometimes preceded and sometimes followed periods when the cows were milked by hand. Only with four cows did the machine-milking periods come within the hand-milked periods, or vice versa, and three of these yielded, on the average, more milk and butter fat on hand-milking than on machine-milking. The explanation of this result and of other differences in the production of the cows on the two methods of milking lies in the natural variations in the dairy production of cows from year to year. These variations are due to various causes, some of which are well understood and others but imperfectly so. The most important factor in the case of good dairy cows is doubtless the intensity of the system of feeding practised. In this respect marked differences occurred with the cows whose records are presented in the table. Pure-bred cows in the university dairy herd, as in the case of practically all dairy herds, have generally received special treatment when tested for advanced-registry records, in the way of liberal allowances of concentrates and green or succulent feed, three or even four times a day milking, etc. They were also placed in separate box stalls, which under the conditions present in our dairy necessitated their being milked by hand. Several of the cows (most of them included

TABLE VII.—PRODUCTION OF MILK AND BUTTERFAT PER LACTATION PERIOD

Machine-Milked							Hand-Milked				
Name of cows	Age, years	Lactation period began	No. days	Milk lbs.	Butterfat lbs.	Per cent. fat	Lactation period began	No. days	Milk lbs.	Butterfat lbs.	Per cent. Fat
Atlantis.....	7	3-16-15	365	7002.9	295.54	4.22					
	8	4-13-16	364	5733.7	231.86	4.04					
	9	5-25-17	354	6932.5	346.48	5.00					
		Average	361	6556.4	291.29	4.44	3-31-14	324	9090.9	409.39	4.50
Santa.....	3	9-12-15	377	9052.5	588.16	6.50	7-18-14	405	5838.9	353.71	6.06*
Willowmoor.....	4	8-9-15	340	8483.8	366.06	4.31	1-31-14	453	11260.2	482.44	4.28
							10-3-16	348	9507.5	431.46	4.55
							Average	401	10383.9	456.95	4.40
							12-20-14	354	5116.9	173.86	3.40
Colantha.....	5	3-16-16	312	6325.4	201.54	3.19	10-3-13	357	5732.0	196.33	3.42
Bess Fayne.....	2	11-11-15	365	8854.0	265.78	3.00	Average	356	5424.4	185.10	3.41
Fern R. P.....	6	2-12-18	404	9845.3	322.90	3.28	12-20-16	334	8216.8	258.64	3.15
		Average	384	9349.6	294.34	3.15	12-28-16	334	8645.6	425.89	4.93**
		8-20-15	306	6294.0	296.67	4.71					
							4-18-14	462	6509.5	357.38	5.49
Marigold.....	5	8-29-16	296	4197.7	254.09	6.05	9-19-15	315	4232.2	252.80	5.97
Hannah.....	6	6-30-15	308	11859.5	373.11	3.15	Average	389	5370.9	305.09	5.68
	7	6-14-16	323	9620.4	316.19	3.29	7-16-13	274	8329.6	271.75	3.26
	8	7-23-17	318	9536.1	322.26	3.38	5-27-14	348	12795.1	431.57	3.37
		Average	316	10338.7	337.19	3.26	Average	311	10562.4	351.66	3.33

*Machine-milked from April 20-July 26, 1915.

**Machine-milked from August 9-November 3, 1917.

TABLE VII.—PRODUCTION OF MILK AND BUTTERFAT PER LACTATION PERIOD—(Continued)

Name of cows	Age, years	Machine-Milked					Hand-Milked				
		Lactation period began	No. days	Milk lbs.	Butterfat lbs.	Per cent. fat	Lactation period began	No. days	Milk lbs.	Butterfat lbs.	Per cent. Fat
Korndyke.....	5	3- 2-15	413	11767.7	417.10	3.54	11- 1-13	410	13443.0	493.84	3.67
							4-17-18	267	9592.1	351.72	3.67
							Average	339	11517.6	422.78	3.67
Agnes.....	4	4-16-15	408	12044.1	388.44	3.23	12-27-13	381	11717.8	394.86	3.37
							10-23-16	318	10620.7	401.30	3.78
							Average	349	11169.3	398.08	3.56
Jap.....	5	3-13-17	507	7736.7	466.75	6.03	1-25-15	360	5010.2	251.00	5.01
							2-11-16	374	5220.3	301.74	5.78
							Average	377	5115.3	276.37	5.41
Begonia II.....	4	5-11-17	307	6468.7	346.19	5.35	5-15-15	277	2670.1	121.44	4.55
Julie.....	4	12-21-17	326	7897.5	293.03	3.71	4-22-16	353	5678.4	297.09	5.23
							Average	315	4174.3	209.27	5.01
Ave, for 13 cows (18 Yrs. lactation periods):... Average per lactation period:.....	4.9 5.4		358 355	8424.1 8314.0	350.00 338.45	4.15 4.07	11-15-16	371	7799.3	318.82	4.09
							Yrs.				
							4	354	7946.9	336.28	4.23
							4.1	353	7953.7	332.24	4.18

in the hand-milked group) were able to produce more milk on account of these favorable conditions, especially the heavier system of feeding, than if they had been kept in the milking barn with the regular string and milked by machine.

The feed records for the cows whose production is given in Table VII have been compiled. None of these cows were pastured during their milking periods. In order to arrive at a definite figure for the total feed consumption of the cows during the lactation period, the number of feed units contained in the rations fed has been calculated and summarized. The equivalents of the various feeding stuffs fed were obtained according to the feed-unit system, the following amounts of the different feeds being considered one feed unit:—

- 2.2 lbs. alfalfa hay
- 6 lbs. Indian corn or sorghum silage
- 7 lbs. green alfalfa
- 8 lbs. green barley, oats or corn
- 10 lbs. beets
- 12.5 lbs. pumpkins
- 1.1 lbs. wheat, bran, oats, or dried beet pulp
- 1 lb. barley or cocoanut meal
- .9 lbs. linseed meal
- .8 lbs. cottonseed meal

Table VIII gives the results of these compilations for the thirteen cows whose records of production are given in the preceding table.

TABLE VIII.—TOTAL NUMBER OF FEED UNITS SUPPLIED IN RATIONS

	Machine-Milked			Hand-Milked		
	Roughage	Concen- trates	Total	Roughage	Concen- trates	Total
Atlantis.....	3869	1941	5810	3810	2959	6769
Santa.....	4652	4199	8851	4264	2120	6384
Willowmoor.....	4527	3620	8147	4648	3521	8169
Colantha.....	3926	2214	6140	3948	1563	5511
Fayne.....	5547	19	5566	5026	.....	5026
F. R. Pearl.....	3981	2471	6452	3815	3402	7217
Marigold.....	3646	1395	5041	4457	2532	6989
Hannah.....	3950	2409	6359	3459	1745	5204
Korndyke.....	4177	2624	6801	4123	3420	7543
Agnes.....	5372	4236	9608	4008	5631	9639
Jap.....	5956	.....	5956	5006	5	5011
Begonia.....	4241	.....	4241	4118	.....	4118
Julie.....	4520	2349	6869	4209	2638	6847
<i>Average.....</i>	<i>4489</i>	<i>2114</i>	<i>6603</i>	<i>4222</i>	<i>2272</i>	<i>6494</i>

If the data for the total feed consumption in Table VIII be compared with the production of the respective cows when milked by machine or hand, it will be seen that, with but few exceptions, the production of milk and butter fat during machine or hand-milked periods follows the feed consumption; wherever the higher production occurs for a given animal, the larger amount of feed eaten will be found, as shown by the total number of feed units consumed during the lactation period.

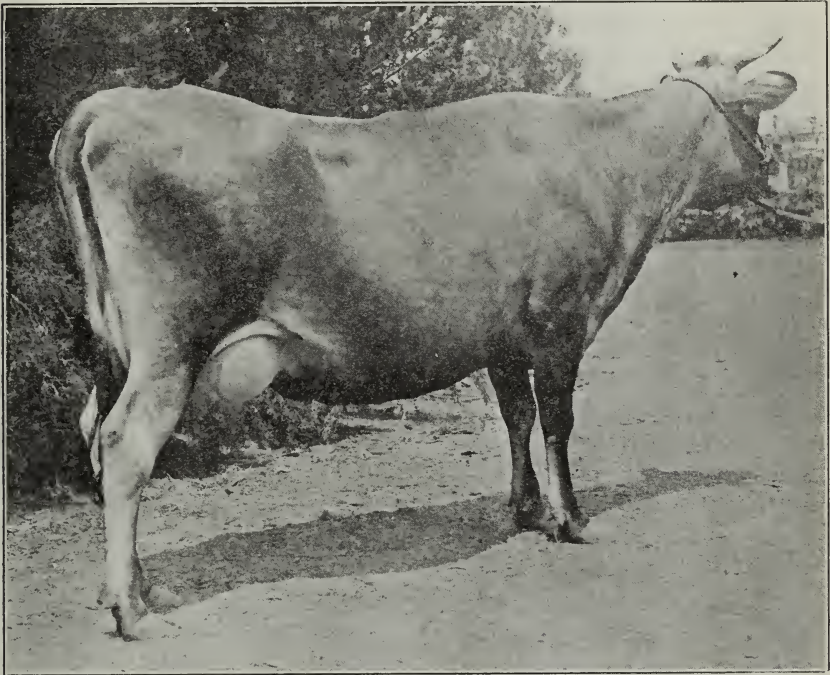


Fig. 3.—Interested Jap's Santa, 296928, owned by the University of California.

This is of course what one would expect and is only referred to here for the sake of the comparison that it affords of the amount of feed eaten by machine-milked and hand-milked cows.

Attention may be called in this connection to the production of the pure-bred Jersey cow Santa (Interested Jap's Santa, 296928) for the lactation period beginning September 12, 1915, when she was milked by machine. She produced during this lactation period, as a three-year old, 9052.5 lbs. of milk and 588.16 lbs. butter fat (average fat content 6.50%). During the following lactation period, beginning March 13, 1917, she produced on hand milking, 13308.5 lbs. of milk and 805.72 lbs. fat (6.05% fat), which was the highest record of pro-

duction for a Jersey cow in the state until the next lactation period, just completed, when she produced 15,569.4 lbs. milk and 940.72 lbs. butter fat. Evidently the fact that this cow was milked with machine for an entire lactation period as a heifer did not interfere with her capacity for an even larger dairy production during the following years (see fig. 3); on the other hand, however, it cannot be stated definitely, that the increase might not have been still greater if she had not been machine-milked at all.

It will be noted from Table VII that the average figures for the production of the cows for the period they were machine milked were 8,424 lbs. milk and 350.00 lbs. fat (average per cent., 4.15), against 7,946.9 lbs. milk and 336.28 lbs. butter fat (average per cent., 4.23) for periods of hand-milking,—a difference of 5.6% in the production of milk and 3.9% in the production of butter fat in favor of machine-milking. If the data for the separate lactation periods included be averaged, it will be found that these differences between the two groups are reduced to 4.3% and 1.8% for the production of milk and butter fat, respectively. The average age of the cows during the periods of hand-milking was somewhat below that for the periods of machine-milking, but, on the other hand, a number of the cows were fed heavier rations when hand-milked than when milked by machine in the regular string, for the reason previously stated. The extent to which these two factors influenced the production of the cows cannot be determined with certainty, but it would seem that they were of nearly equal importance in the case of the two groups of cows. A study of the data presented in the table by the statistical method will show that the natural variations in yearly production by the cows are far greater than the difference between their average production when machine-milked and when hand-milked. The same conclusion may therefore be warranted from a consideration of the data presented in Table VII as in the case of those in Table VI, that the special method of milking practised does not, on the whole, affect appreciably the dairy production of the cows, provided the milking is done with equal care in either case. This result is fully corroborated by investigations of the efficiency of milking machines conducted by other experiment stations, notably those of the Wisconsin and Geneva (N.Y.) stations. According to the latter station,* “the only conclusion possible to draw, from trials extending over five years and including a large number of lactation periods, is that machine-milking, if properly done, does not influence the flow of milk to any extent capable of measurement.”

*Bulletin 353, Nov. 1912.

The fluctuations in milk flow that frequently occur during different lactation periods in the case of individual cows are determined by a variety of factors, as previously suggested; of these, the intensity of the system of feeding adopted, the age, and the "condition" of the cow, are of marked influence. Evidently the method of milking practised is not an important factor in determining the amount of milk or butter fat obtained during the lactation period, when the milking is carefully done. Nearly all cows take readily to machine milking, especially young heifers, and under similar conditions they will, as a general rule, yield as much milk when milked by machine as by hand if they are always promptly stripped by hand after the machine is removed. Cases in which cows do not do well on machine-milking are very exceptional, being mostly those of old cows of a nervous disposition. Such cows, and cows that cannot very well be milked by machine on account of unusual size or shape of teats or uneven udders are preferably milked by hand or disposed of when a change to machine milking is made in a herd.

SUMMARY

The modern milking-machine is a practical and safe labor-saving device. This has been proved by the results of carefully conducted experiments at our own and other experiment stations, and is also borne out by the experience of practical dairy farmers in all parts of the country during the past dozen years or more. At the present time there are eight different makes of milking machines on the market in this state, any one of which may be confidently expected to do satisfactory work in the hands of a careful operator. Failures in machine-milking have been rather numerous in the past, from a variety of causes, chief among them being perhaps the fact that the owner did not fully understand the mechanics of the machines or appreciate the necessity of care in operating and keeping them clean, or of following up the machine-milking promptly by careful stripping. Of late years the failures have, however, greatly decreased in number, as the machines have been further improved in simplicity and efficiency, and the conditions for their successful operation are better understood. It is safe to say that a dairyman who introduces machine-milking into his herd with any standard make of machine on the market is now as much on trial himself as is the machine. The best remedy for failures in machine-milking is to become thoroughly familiar with the machine adopted, its adaptation to individual cows, and the requirements for keeping it in a mechanically perfect and sanitary condition.

Milking-machines have not as yet been as generally adopted in the dairy districts of our country as, for instance, in Australia and New Zealand. According to reliable reports received, there are but few dairies of over thirty cows in these countries that are not milking by mechanical means, and many smaller dairies are likewise using milking-machines. With the present scarcity of reliable, efficient milkers, and the high cost of labor, feed, and dairy supplies, the necessity of reducing the cost of milk production becomes greater than ever before. It is possible to do this by either or both of the following methods: By increasing the production of the dairy herd through culling, use of good pure-bred sires and modern methods of feeding and management, or by reducing the operating expenses of the dairy. The milking-machine is an important aid in reducing these expenses. The days of hand-skimming of milk are long gone by, and everything points to the fact that we have now entered upon an era of machine-milking. It is the next step in the economical, efficient management of fair-sized or large dairies, and the experience of other dairy countries in regard to milking-machines will undoubtedly be duplicated in this country.

The investigations of this and other experiment stations have shown that milking-machines properly operated do not injure the udders of cows, or cause garget or other udder diseases. Udder troubles are often due to causes that are not in any way associated with the method of milking practiced; they will occur at times in machine-milked, as well as in hand-milked herds, although less frequently when ordinary care is taken in operating the machine. The best way to avoid troubles of this kind in case of machine-milking is to remove the machine as soon as no more milk comes down, and to finish the milking by hand without unnecessary delay. Prompt and careful hand stripping is a most important factor in successful machine-milking; even though the machine used leaves only very small amounts of milk to be stripped out.

In the selection of the particular make of machine, a number of points should receive consideration, besides first cost and nearness to service agency, such as cost of up-keep, depreciation, simplicity of mechanism and of cleaning. The various machines on the market differ considerably with regard to these points, and it is evident that no one machine stands out above the others in all respects; also that any farmer with a fair degree of intelligence and resourcefulness need not hesitate to install a milking-machine in his dairy if he keeps twenty or more cows. In many cases it may prove advantageous to adopt machine-milking also in dairies of twelve to fifteen cows, as it will make the owner less dependent upon or entirely independent of hired help. The actual saving in the cost of milking by machine over hand-milking is,

however, greater in the case of large herds than with small ones and will, in general, be in proportion to the size of the herd. It has been shown that with proper care, and with careful, prompt hand-stripping, milking-machines will have no appreciable effect one way or the other on the dairy production of the cows or on the general welfare of the herd, but they will not long render satisfactory service with careless handling and lack of cleanliness. For this reason, milking-machines are most likely to prove successful when operated by the owner himself or by help directly interested in their success.

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